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CLINICAL REVIEW

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Pregnancy and obesity: practical implications

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Abstract Obesity is presently the most prevalent health threat in the western world, and its influence on general health is rapidly increasing. Obesity has also developed as a major and frequent risk factor for pregnancy complications. Complications often encountered in obese pregnant women are hypertensive disorders, gestational diabetes mellitus, caesarean section, and postpartum and postoperative infections. The incidence of pulmonary embolism and primary postpartum haemorrhage is most likely also increased. Anaesthetic complications are more frequent. Neonatal consequences of obesity include an increased rate of congenital anomalies, stillbirth, and macrosomia. This article focuses on practical implications of obesity in pregnancy and childbirth for the caregiver.

Keywords Pregnancy · Obesity · Overweight · Pregnancy complications · Labour complications

Introduction

Obesity is an increasing plague in modern medicine. The threat obesity poses is the morbidity accompanying this clinical state. Individuals with metabolic syndrome, also called syndrome X and characterised by high levels of triglycerides and serum glucose, a low level of high-density-lipoprotein cholesterol, high blood pressure, and abdominal or central obesity, are at high risk of developing type 2 diabetes and coronary heart disease.

Obesity has become the second leading cause of death in developed countries [1]. Not only older people suffer from this disorder, but more and more younger people are affected. Consequently, gynaecologists will increasingly face pregnant patients suffering from overweight or (morbid) obesity. Nowadays, preconception overweight is the most common high-risk factor in pregnancy.

Around 1940, the first articles in the English literature on the subject of pregnancy and obesity were published [2–4], stating that obesity increases the hazards of childbearing. Since then, numerous review articles have highlighted the subject [5–7]. This article focuses on the practical implications maternal obesity has for clinical obstetrical practice.

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Definition

Obesity may be defined as an abnormal state of health in which there is excessive body fat. Absolute weight or percentage of weight above the ideal body weight for height was used as an index in the older literature. Nowadays, obesity is most frequently defined in international literature on the basis of the body mass index (BMI), or Quetelet index. The Belgian mathematician and astronomer Quetelet developed this measure in the first half of the 19th century. BMI is the weight in kilograms divided by the square of the height in meters. An individual's nutritional status can be evaluated using the BMI percentiles, which are age-, gender-, and population-specific. For adults, the World Health Organization (WHO) defines a BMI <19 kg/m^2 as lean or underweight, a BMI between 19 and 24.9 kg/m^2 as normal, a BMI between 25.0 kg/m^2 (85th percentile) and 29.9 kg/m^2 as overweight, and a BMI of 30 kg/m^2 (95th percentile) or greater as obese. Obesity is classified as class I (30–34.9 kg/m^2), class II (35–39.9 kg/m^2), or class III (>40 kg/m^2) [8] (Table 1). In women, BMI percentiles are greater than in men. The 85th percentiles for women rise from the age of 20 to 40 years from 25 to 29 kg/m^2, respectively, and the 95th percentiles from 32 to 36 kg/m^2 [9].

Table 1 World Health Organization weight classification [8]

	Body mass index (kg/m^2)
Underweight or lean	>19
Normal	19–24.9
Overweight	25–29.9
Class I obesity	30–34.9
Class II obesity	35–39.9
Class III obesity	>40

In different ethnic and racial groups, BMI may reflect different levels of fat mass. Using a BMI of 30 kg/m^2 for Caucasians as a reference point, the levels of obesity in terms of percentage of body fat indicate that the BMI for Indonesians, Thais, and Ethiopians could be as low as 27 kg/m^2, and in blacks and Polynesians this cut-off should be higher than 30 kg/m^2 [10, 11]. American Caucasians have higher percentages of body fat. Therefore, between black and white American adults, BMI and fat mass were found to have similar proportions [12]. The European situation is similar. Although the incidence of obesity in Europe varies greatly, BMI reasonably reflects the percentage of body fat in different European populations [13].

Morbid obesity or clinically severe obesity is strongly related to disease processes but is not uniformly defined. Commonly it is defined as a BMI of 39–40 kg/m^2 or greater. Another definition of morbid obesity is a weight 50–100% above the ideal body weight or more than 100 lb or 45 kg above that weight. WHO defines morbid obesity as more than two times the ideal body weight.

In many articles concerning pregnancy and pregnancy complications, the prepregnant or early pregnancy body weight is used to calculate BMI. In 50% of pregnant women, BMI does not increase substantially during pregnancy. In the other 50%, BMI rises more than 5 kg/m^2 [14]. One study describes the course of BMI during pregnancy [15]. The BMI itself cannot be used accurately during pregnancy because it provides no information on whether weight changes occur as a result of differences in total body water, fat-free mass, or fat mass. In a study of nonobese pregnant women, a significant correlation between BMI and percentage of body fat prevailed throughout pregnancy. Despite this finding, predicting the percentage of body fat using BMI during pregnancy is practically hampered by the large range [15]. No studies describe this relationship in obese pregnant women. When compared with lean women, the accumulation of fat mass in obese women during pregnancy is relatively smaller, which suggests that BMI in obese women does not reflect a constant correlation between BMI and body fat, unlike in nonobese women [16].

Another simple way to diagnose obesity is to measure waist circumference in standing position at the end of gentle expiration at the level midway between the lower rib margin and the iliac crest. The cut-off points of waist circumference for mild and severe abdominal obesity are 94 and 102 cm, respectively, in men and 80 and 88 cm in nonpregnant women. Using this parameter, severe obesity in women is found to be more than twice as common as in men [17].

Although BMI is the most frequently used anthropometric parameter for body composition, newer and more precise methods are available now. These methods measure body composition more accurately and describe the differentiation between lean mass and fat mass better. Examples of noninvasive body composition measuring methods are bioelectrical impedance analysis, hydrodensitometry (underwater weighing), and air displacement plethysmography. Body composition during pregnancy is probably better assessed using these methods [15, 16, 18–20]. Although most of these methods can be used in pregnancy, they are impractical and more time-consuming than the traditional methods. Also, a number of these methods need correction for use during pregnancy [21]. The BMI cut-off point for obesity (30 kg/m^2) corresponds with a percentage of body fat of over 25% in young adult males and 35% in young adult females. However, as was stated before, the relation between BMI and percentage of body fat is not uniform among populations.

Incidence

Worldwide there is a continuous increase in the frequency of overweight and obesity. The difference between the prevalence in different countries is still large. In the United States, obesity is the most common chronic disease, affecting more than 1 in 4 of all Americans, including children, and its incidence has been steadily increasing for the past 20 years. In Europe, Australia/New Zealand, the Middle East, and other American countries, the occurrence of obesity appears to be increasing and is now between 10% and 20%. Among women the prevalence of obesity varies in Europe from 11% in the Netherlands to 24% in Spain [1]. The prevalence of obesity is still fairly low in China, Japan, and many countries in Africa. Exceptionally, in Japan the mean BMI in younger women, especially those in metropolitan areas, has decreased, although the prevalence of overweight in Japanese men and elderly women has increased during the last 20 years [22]. A similar and hopeful observation was made in German schoolchildren [23]; both BMI and waist circumference tend to be greater during winter compared with summer. In studies that describe the prevalence of obesity in a population, this should be taken into account [17].

The importance of heredity has been highlighted by several authors. For example, children of two obese parents have a 50% likelihood of becoming overweight themselves [24]. However, this cannot explain the present epidemic of obesity entirely. Genes in combination with changes in lifestyle may best explain the present situation [25]. A recent study found that obese women have more children than lean women, indicating a role for genetics [26]. The latter finding exists despite the increased number of reproductive disturbances in obese women [27]. This subject is not discussed further in this article.

Complications during pregnancy

Duration of pregnancy

After treatment for subfertility, spontaneous abortion is increased in obese women [28]. The risk of spontaneous abortion in subfertile patients increases with BMI and is more than doubled in morbidly obese women. In a population of recipients of oocyte donation, obesity doubled the chance of spontaneous abortion [29]. Comparing these studies is sometimes difficult because of the different definitions used for obesity. Figures on incidence of spontaneous abortion in the general population are scarce. Although this increased incidence is consistent in the subfertile subpopulation, it is also found, but to a lesser extent, in the general population [30, 31]. Other studies that found no differences did not discern between early and late abortions [32, 33]. A possible explanation for the higher abortion rate could be the endogenous estrogen stimulation of the endometrium prior to implantation, causing unfavourable intrauterine surroundings. Late abortion seems to be unrelated to obesity [30].

The impact of obesity on preterm delivery rates is not consistent. A recently published study showed a clear association between maternal BMI and spontaneous and induced preterm birth [34]. Spontaneous preterm delivery decreased from 16.6% in lean women to 5.2% in classes II and III obese women. The incidence of preterm delivery was twice as high in nonobese women at <37, <34, and <32 weeks. Some other large studies found an increased percentage of preterm deliveries in obese patients. In a large Swedish study and in another large American study, an increased incidence was seen only in obese nulliparous women for deliveries before 32 weeks [35, 36]. A large British study found a significant inverse relationship of overweight and obesity with preterm delivery before 32 weeks [37]. The study by Bianco et al. [38] found no difference but only a trend. In this study, demographic characteristics differed significantly. The group of morbidly obese patients contained twice as many black or Hispanic women as the nonobese group, which is considered an independent risk factor for preterm delivery. In the study by Weiss et al. [39], an increased preterm delivery rate was seen only in morbidly obese women, with an odds ratio (OR) of 1.5 and a 95% confidence interval (CI) of 1.1–2.1. Other studies found a 2–10 times lower incidence of preterm delivery in morbidly obese patients compared with nonobese patients [40, 41]. A possible explanation could be the increased incidence of gestational diabetes in morbidly obese patients. The influence of abnormal glucose metabolism on the incidence of preterm delivery has been shown [42]. Studies that controlled for this variable found no increased incidence of preterm delivery in obese patients [36, 41].

Prolonged pregnancy is associated with obesity [37, 43, 44]. The prevalence of deliveries after 42 weeks of gestation almost doubles [37]. The reason for this phenomenon is still obscure. The combination of a possibly lower incidence of preterm deliveries, higher incidence of postterm deliveries, and increased inadequate contraction pattern during the first stage of labour suggests an influence of obesity on myometrial activity [45].

Gestational diabetes mellitus

Not surprisingly, obese women have 3–10 times higher rates of preexisting hypertension and pregestational diabetes [37, 40]. Gestational diabetes mellitus (GDM) is commonly defined as glucose intolerance first detected during pregnancy. Clinically, GDM becomes manifest in late gestation, when 70% of foetal growth occurs.

The risk of developing GDM is strongly influenced by excessive maternal pregravid weight [39, 46]. Fasting insulin levels are higher in obese pregnant women than in nonobese pregnant women [47]. To obtain normoglycaemia, insulin levels are increased in obese pregnant women. Obviously, this will not always be enough, and in obese women the usual rise in insulin resistance during pregnancy is exaggerated. In obese women, insulin resistance is already increased before conception without clinical symptoms [48]. In overweight women, the risk of developing gestational diabetes is 1.8–6.5 times greater than in nonobese women. In obese women the incidence rises 1.4–20 times to a percentage between 6% and 11% [5, 49, 50]. In a large prospective multicentre study, the incidence of GDM in morbidly obese women (BMI >35 kg/m^2) was 9.5% versus 2.3% in the control group (BMI 19.8–26 kg/m^2) [39]. In a group of women with BMI >40 kg/m^2, the incidence of GDM rose even to 24.7% [40].

The diagnostic criteria for GDM are still under debate. In view of the high prevalence of GDM in obese women, screening should begin after the 20th week of gestation and be repeated at regular intervals, as GDM may eventually develop with increasing gestation. In many studies that mention the prevalence of GDM, different diagnostic criteria are used. Sometimes it is not even clearly stated which test was used [37, 40]. The formal 2-h 75-g oral glucose tolerance test is considered the most accurate one. WHO's diagnostic criteria for GDM are a fasting glucose of ≥7.0 mmol/l or a 2-h glucose ≥7.8 mmol/l [51]. A more practical 1-h postprandial plasma glucose test as a screening tool for GDM offers high sensitivity and specificity [52].

Fasting levels of glucose in early pregnancy cannot be used to predict the development of GDM later in pregnancy [53]. To screen for GDM later in pregnancy, measuring fasting plasma glucose concentrations identifies 70% of women with GDM [54]. It is advisable to screen obese women at their first visit for subclinical hyperglycaemia.

Women who develop GDM are at an increased risk of also developing preeclampsia. Obesity is a major confounding factor in this relationship [55, 56].

Preeclampsia

The incidence of pregnancy-induced hypertension (PIH) and preeclampsia is influenced by maternal overweight. From lean to obese women, the prevalence of PIH rises linearly with increasing pregravid BMI [39, 57].

In a systematic review of 13 cohort studies, a consistent and linear rise in the risk of preeclampsia was observed with increasing BMI. The risk of preeclampsia doubled with every 5–7-unit increment of the pregravid BMI [58]. For clinical practice this means that the incidence of preeclampsia increases from 3–4% in normal-weight women to more than 15% in morbidly obese women. One of the possible explanations may be the endothelial dysfunction induced by chronic hypertriglyceridaemia in women with syndrome X [59]. Based on this linear model, a prepregnancy weight reduction of 1 kg/m^2 may decrease the rate of preeclampsia by 0.54%.

One of the forms of preeclampsia, the HELLP syndrome (haemolysis, elevated liver enzymes, and low platelets), is probably not influenced by maternal weight. So far, only one study has described this relationship [60].

One of the more serious complications of preeclampsia is eclampsia. The incidence of this complication also follows a linear pattern with BMI. In obese women, eclampsia is more frequent (OR 3.0; 95% CI 2.1–4.4) than in lean women. This, however, is not higher than expected on the basis of the increased incidence of preeclampsia [36]. In women with HELLP syndrome, eclampsia occurs predominantly in women of lower weight [60].

Blood pressure measurement

Blood pressure measurement in the obese must be performed according to standard recommendations. It should be measured with the auscultatory technique by a trained observer and a mercury sphygmomanometer using the 1st and 5th phases of the Korotkoff sounds for systolic and diastolic values [61]. In most countries the gold-standard mercury sphygmomanometer is not used anymore and has been replaced by aneroid sphygmomanometers. Another important recommendation, especially in pregnant patients, is that the measurement should be carried out in sitting position using the antecubital fossa of the right arm. Home readings are probably better suited to monitor the effect of treatment, but this does not seem very practical for pregnant patients.

Finally, in obese patients the cuff size is of utmost importance. Correct measurement of blood pressure requires using a cuff that is appropriate for the size of the upper right arm. Following American Heart Association guidelines, the optimal cuff has a bladder length that is 80% and a width that is at least 40% of the arm circumference midway between the olecranon and the acromion. The error between the gold-standard intra-arterial and auscultatory blood pressure is minimal with a cuff width of 46% of the arm circumference [62]. Recommended cuff sizes are shown in Table 2. The standard cuff width of 12 cm is usually not suited for obese patients. Too small an inflatable bladder can lead to false readings of elevated blood pressure in the range of 3.2/2.4 to 12/8 mmHg and as much as 30 mmHg in the obese. Using the standard cuff size leads to overestimating blood pressure in more than 5% of obese pregnant patients [63]. An excessively large bladder may lead to falsely low readings in the range of 10–30 mmHg. Morbidly obese patients with large, conical arms >41 cm in circumference may require the blood pressure to be measured on their forearms, with the sounds listened to over the radial artery, although this may overestimate both the systolic and diastolic blood pressures [64, 65]. An alternative is to use a wrist blood pressure monitor held at the level of the heart [66]. Blood pressure measurement at the ankle is comparable to arm measurements. Because ankle systolic blood pressure is physiologically higher, the mean arterial pressure at the ankle is higher. It is questionable whether this technique is more feasible in morbidly obese patients whose brachial blood pressure cannot be measured [67, 68]. For excessively obese women (BMI ≥60 kg/m^2), invasive arterial monitoring is often the only possible means of blood pressure measurement [69].

Weight gain

In nonobese women the relationship between maternal weight gain during pregnancy and foetal weight has been established. This relation is also present in morbidly obese women. Every kilogram of maternal gestational weight gain was found to increase birth weight by 44.9 g in underweight women, 22.9 g in normal-weight women, and 11.9 g in overweight women. For every extra kilogram of weight not lost after delivery, birth weight was increased by 35.6 g in underweight women, 15.9 g in

Table 2 Recommended blood pressure cuff sizes in relation to arm circumference [61]

Arm circumference	Cuff size
22–26 cm	12×22 cm
27–34 cm	16×30 cm
35–44 cm	16×36 cm
45–52 cm	16×42 cm

normal weight women, and 5.1 g in overweight women, thus suggesting that in overweight women, excessive weight gain is least effective in adding extra weight to the foetus [70]. In morbidly obese women, no weight gain versus a weight gain of more than 15 kg resulted in an increase in the incidence of large-for-gestational-age (LGA) infants from 12% to 24%, but the absolute birth weight increased by only 150–200 g [38]. Surprisingly, in general, obese women were found to gain less weight than nonobese women during pregnancy [71, 72].

The influence of weight gain on obstetric complications seems to disappear when women become more obese. Preterm delivery was not associated with weight gain during pregnancy in pregravid obese women. Weight gain proved to be a risk factor for preterm delivery only in lean and normal-weight women and only when weight gain was low [41]. In classes II and III obese women (BMI >35 kg/m^2), complications such as gestational diabetes and preeclampsia were not influenced by the magnitude of weight gain but only led to an increase in neonatal complications [38]. In a recent study, these results were confirmed. Excessive weight gain in obese and morbidly obese women did not lead to higher rates of obstetric complications [14]. However, in normal weight and overweight women, the magnitude of maternal weight gain not only influenced neonatal complications but also obstetric complications [73]. In overweight women, the incidence of preeclampsia and gestational diabetes increased concomitantly with greater maternal weight gain.

To prevent neonatal complications, it seems of interest to limit the magnitude of weight gain in overweight and (morbidly) obese women. The following recommendations for weight gain during pregnancy are from the Institute of Medicine: A woman with a low BMI (<19.8 kg/m^2) should gain a total of 12.5–18 kg during pregnancy, a woman with a normal BMI (19.8–26 kg/m^2) should gain a total of 11.5–16 kg during pregnancy, and a woman with a high BMI (>26–29 kg/m^2) should gain a total of 7–11.5 kg during pregnancy. Adolescents and black women should strive for gains at the upper end of the recommended range. Short women (<157 cm) should strive for gains at the lower end of this range. Obese women (BMI >29 kg/m^2) have a separate recommended target weight gain of about 6 kg [74]. Unfortunately, the recommendations are ineffective for preventing LGA infants in obese women because of the diminished influence of maternal weight gain on foetal weight in this group of women [75].

Active management with guidance by health care providers and an educational programme did not prove to be effective in preventing women from gaining excessive weight [76, 77]. Only in a low-income subgroup of overweight women did the programme influence excessive weight gain; weight gain in this subgroup was reduced by half [76]. A Cochrane review concluded that protein/energy restriction in obese women during pregnancy may even be harmful to the developing foetus [78]. In obese women, suboptimal weight gain gives rise to an increased number of small-for-gestational-age (SGA) infants [72].

Foetal growth

Obese women are at risk of delivering LGA infants. They give birth 1.4–18 times more frequently to LGA infants than nonobese women do [5]. Pregestational diabetes and pregravid obesity have been found to independently influence foetal weight. Pregestational diabetes has the greatest influence on foetal weight in lean and normal-weight women. With increasing BMI, foetal weight is merely determined by pregravid obesity [79]. In a cohort of glucose-tolerant Danish women, LGA infants were more frequently born to obese women (OR 2.5, 95% CI 1.8–3.6) [71]. This is in agreement with the finding that preventing macrosomia by normalising maternal glucose levels has been ineffective in obese women [80]. Consequently, obese women can be expected to deliver fewer SGA infants. In large epidemiological studies, this expectation was confirmed [14, 35, 36, 44].

Foetal weight estimation

For clinical decisions, an estimation of foetal weight is often necessary. This pertains especially to the very small, often preterm, foetus and to the very large foetus. Although the general opinion is that foetal weight cannot be estimated adequately in obese women, the accuracy of foetal weight estimation is neither clinically nor sonographically influenced by maternal body size whether a women is lean or obese [81, 82]. The absolute percent errors of weight estimation were the same for lean and obese women. Half of all sonographic estimations were within the 5% range of the actual birth weight [82].

Stillbirth

In obese women the risk of sudden unexplained intrauterine death increases linearly with increasing pregravid weight [37, 83, 84]. The risk of antepartum death was found to double irrespective of gestational age in obese women versus lean women (OR 2.1, 95% CI 1.2–3.6). Overweight and obese women face almost a threefold increase in term stillbirth compared with lean women. The amount of weight gain did not influence these figures [85]. The higher incidence of GDM and preeclampsia partly explains the higher stillbirth rate in obese women. Other factors may be differences in lifestyle and smoking habits.

Congenital anomalies

Growing evidence shows that obesity is associated with an increased risk of congenital malformations [86]. In one large German study, the prevalence of congenital malformations diagnosed antenatally and at follow-up was 11.1% in obese women, which is 4% higher than in the general population [87]. Neural tube defects are the most frequent congenital anomalies found in the offspring of obese women. In obese women, spina bifida is at least twice as frequent as in nonobese women and probably follows a linear curve with maternal weight [88, 89]. A retrospective population-based study in Canada concluded that the OR for neural tube defects was 1.2 (95% CI 1.1–1.3) per 10-kg incremental rise in maternal weight [90]. Folic acid supplementation did not influence the observed increase in neural tube defects in overweight and obese women [89]. An improper diet and reduced physical activity, prevalent in many obese women, are associated with an increased risk of neural tube defects [91, 92].

Omphalocoele, but not gastroschisis, is more frequent in the offspring of obese women. Multiple anomalies and heart defects are almost twice as prevalent in children of overweight and obese women [88, 93].

Possible causal factors for this greater incidence in foetal anomalies are altered glycaemic control mechanisms, (subclinical) diabetes mellitus, and maternal malnutrition due to poor-quality diet during the periconceptional period and early pregnancy. Several studies show that multivitamin supplementation in obese women cannot eliminate the increased risk [94], whereas in nonobese women the incidence of congenital anomalies is effectively lowered by multivitamin supplementation [93].

The need for structural anomaly screening in all obese pregnant women is strongly advised considering the aforementioned evidence.

In some studies, dizygous twin gestations were found to be more common in obese women. However, in these studies obese women were older than normal-weight women [44, 95]. In the most recent study, even after correction of the maternal age, dizygous twinning was still doubled in obese women [95]. One study defined obesity as >90 kg at some time during pregnancy [44]. Nowadays, many women in this study would not have met the criteria for overweight or obesity.

Structural ultrasound

Ultrasonic visualisation of foetal structures was initially hampered by maternal obesity [96, 97]. More recent studies report no influence or only a small influence of maternal habitus on the visualisation of foetal structures when structural ultrasound is carried out later than 18 weeks' gestation [98]. New techniques may be valuable in improving the quality of ultrasound images in obese women [99]. Tissue harmonic imaging has been shown to improve the images in foetal echocardiography in obese women [100]. However, despite these new technical possibilities, obesity remains a problem in performing adequate structural ultrasound [101].

Alternatives to the routine abdominal ultrasound may be transvaginal or transumbilical ultrasound. In obese women, transvaginal sonographic imaging of early 2nd-trimester foetal anatomy may be facilitated by uterine fundal pressure [102]. This method is effective only until the 17th week of gestation. After filling the umbilicus with ultrasound transmission gel, transumbilical placement of the vaginal probe may substantially improve resolution, especially of the foetal cardiac structures [103, 104].

Complications during labour and the puerperium

Labour and delivery

In most studies obesity is associated with a 1.7-fold to 2.2-fold higher frequency of labour induction, mostly due to the increased rate of macrosomia and other pregnancy complications [5, 37, 71]. But even after adjustment for these risk factors, the induction rate remains higher in obese women [42, 71].

Labour progression in overweight and obese patients is significantly slower than in normal-weight women. Maternal weight is independently and proportionally associated with prolonged labour and slower cervical dilatation [105]. Especially during the first stage of both spontaneous and induced labour, the uterine contraction pattern seems to be inadequate [105, 106]. After 6 cm of cervical dilation, progression is comparable in both obese and nonobese women [45], and during the second stage of labour, obese women have similar intrauterine pressure profiles as nonobese women do [107]. Perception of uterine contractions is inversely related to maternal weight. This finding was more pronounced in nulliparous women than in multiparous women [108].

Intrapartum foetal heart rate abnormalities, cord accidents, and meconium-stained amniotic fluid occur more often in obese parturients [42, 46].

In most studies, operative vaginal delivery is not increased in obese women despite the increased rate of macrosomia. This unexpected finding is explained by the higher rates of caesarean section in obese patients [37].

In the report of the British Confidential Enquiry into Stillbirths and Deaths in Infancy for the years 1994 and 1995, fatal shoulder dystocia was frequently seen in association with maternal obesity and foetal macrosomia. The positive predictive value of obesity for predicting fatal shoulder dystocia is very low, 13/42,000 for BMI >35 kg/m^2, and 4/10,000 for BMI >40 kg/m^2 [109]. In a study by Robinson et al., shoulder dystocia was found to be strongly related to foetal macrosomia; as in other studies, obesity was not an independent risk factor for shoulder dystocia [110, 111]. It can be concluded that for obese women, the same predictors for shoulder dystocia apply as for nonobese women [111]. The risk of shoulder dystocia was 33% in vaginal deliveries of infants with birth weights $>4{,}500$ g and only 2% in infants with birth weights <4,500 g. These figures must be interpreted cautiously because they are based on a relatively small sample size [112].

In all studies, delivery by caesarean section is at least twice as frequent in obese women [39, 70, 71, 113, 114]. Obesity appears to act linearly with maternal weight on caesarean section rates [42, 115]. This increase is not related to and prevails over the increased prevalence of GDM in obese women [114]. One study showed that the OR for performing a caesarean section increases by 1.29 (95% CI 1.26, 1.32) with every 3-unit increment of the pregravid BMI. This means a fivefold increase in caesarean section rate when BMI increases from 15 to 35 kg/m^2 [113]. Another study calculated that for every unit increment, the risk of caesarean section increases by 7% [116]. In morbid obesity (BMI >40 kg/m^2), caesarean section rates vary from 15.2% to 45.9% [36, 38, 40, 43, 115]. One study reported an incidence of 47.4% in nulliparous morbidly obese women [39]. The risk for caesarean section also increases linearly with maternal weight gain [42, 117]. Both elective and emergency caesarean sections are equally increased in obese women [37]. Suboptimal uterine contraction patterns and soft-tissue dystocia due to fat deposition in the pelvis may give rise to the higher number of nonelective caesarean sections for cephalopelvic disproportion or failure to progress.

Vaginal birth after caesarean section (VBAC) is negatively influenced by pregravid overweight [118]. VBAC success rates are strongly dependent on prepregnancy weight and were found to be 81.8% in women <90 kg, 57.1% in obese women (90–136 kg), and only 13.3% in women with morbid obesity (>136 kg). In the morbidly obese women, elective caesarean sections were more often performed [119]. Significant weight reduction in overweight women between pregnancies did not influence VBAC success, but an increase in weight from normal to overweight led to a decreased VBAC success rate [120].

The success rate of external cephalic version (ECV) in cases of breech presentation is not influenced by obesity [121]. Even in morbidly obese patients, ECV has been carried out successfully [122].

Foetal surveillance

Obesity affects to a minor degree the quality of external cardiotocographic registration [123]. Nonreactive nonstress tests were not more frequently observed and showed no false negative results in obese patients [124]. Nevertheless, it is often difficult to obtain continuous external cardiotocographic signals in obese women [125, 126]. In cases in which foetal surveillance is warranted, an alternative to electronic foetal monitoring is to auscultate the foetal heart tones for a few minutes a couple of times a day. During delivery a scalp electrode will almost always be necessary to achieve continuous electronic foetal monitoring in obese women.

In delivery of twins, foetal surveillance of the second twin may be difficult in obese women. Unsatisfactory surveillance of the second twin may be a reason for performing a caesarean section.

Technique of caesarean section

Standard practice is to position the patient on the operating table in a 10–15º left lateral tilt. In obese patients this is probably even more important for reducing maternal hypotension and its consequences. The operating table should be constructed to allow this position. However, to date there is no scientific evidence for this practice [127].

The abdominal incisions used for caesarean section are the midline incision, Maylard incision, Cohen incision, and Pfannenstiel incision. A vertical incision is associated with a substantial increase in wound infections compared with transverse incisions (OR 12.4, 95% CI 3.9, 39.3) [128]. Another study found that subcutaneous skin thickness is the only significant risk factor that correlates with wound infection. In this study there was a suggestive trend towards more infections after vertical incisions (23% versus 6%). Furthermore, subcutaneous skin thickness is usually greater at the site of vertical incisions than at the site of transverse incisions [129]. An alternative incision, the supraumbilical vertical incision, was not related to more postoperative morbidity in morbidly obese patients than the transverse approach. This incision is suited for the extremely obese patient. A disadvantage is that a classical vertical uterine incision must be made in the fundus [130].

Suturing the subcutaneous fat layer reduces postoperative wound disruption when the fat layer is at least 2 cm deep, but wound infections have not been shown to be reduced by subcutaneous closure [131]. The use of subcutaneous drainage does significantly reduce wound infections in fat layers of >2 cm [132].

To reduce infectious complications after caesarean section, the preventive use of antibiotics is the only proven intervention. The choice of abdominal incision is, as stated before, probably important in this respect.

Anaesthetic complications

The number of complications and the risk of anaesthesia are increased in obese women. A review on this subject was published by Endler [133]. Morbidly obese women have higher rates of failed epidurals and of difficult intubation. Inability to identify landmarks, difficulty in placing the regional block, and erratic spread of the anaesthetic solution contribute to the failure rate. The high initial failure rate necessitates early catheter placement, critical block assessment and catheter replacement when indicated, and provision for alternative airway management [134]. For optimal care, antepartum screening and evaluation by the anaesthesiologist are warranted.

Local anaesthetic techniques may be difficult and time-consuming in obese women. This should be taken into account when the decision for an emergency caesarean section is considered during delivery.

Obese patients experience the same amount of pain during labour as nonobese women and have been found to be more satisfied with pain relief measures [135].

Resuscitation complications in the morbidly obese patient have been described thoroughly in a review by Brunette [136].

Maternal mortality

Obesity in general is considered a major risk factor for health problems and is causally related to chronic diseases and all causes of mortality. More than 60 years ago, maternal mortality was reported to be double in obese pregnant women [4]. The most recent report of the British Confidential Enquiry into Maternal Death assessed 391 maternal deaths over a period of 3 years, from 2000 to 2002, and concluded that depression and obesity are the major causes of maternal death in the United Kingdom. About 35% of the deceased women were obese, which was 50% more than in the general population [137].

Postpartum complications

In morbidly obese patients the incidence of endomyometritis is almost three times higher than in nonobese patients and amounts to nearly 10%. After controlling for the increased rate of caesarean sections in this group, the OR was 1.5 (95% CI 1.1–2.1). In massively obese women weighing >136 kg, the incidence of postoperative endomyometritis was even higher, 32.6% versus 4.9% in normal-weight women [138]. The incidence of wound infection more than doubles in obese patients [37, 139]. Postcaesarean infection was found to double with every 5-unit increment of the BMI [140]. The risk of postoperative infection can be reduced by prophylactic antibiotics [139]. It is still questionable whether changes in the current dosage, timing, and duration of antibiotics in obese patients may lead to a further reduction in infectious morbidity. Simple measures such as reducing the number of vaginal examinations and early intervention with oxytocin have also been shown to reduce infection rates [139].

Surprisingly, the incidence of postpartum haemorrhage varies, from no increase to a 70% increase in morbidly obese women [37, 38]. Blood loss is always difficult to quantify, and a more useful outcome could be the number of red blood cell transfusions given. Higher BMI is nevertheless strongly correlated with postpartum anaemia. In morbidly obese women, the risk increased 2.8 times (95% CI 1.7–4.7) [141]. In morbidly obese women, blood loss during caesarean section is, as can be expected, greater than in normal-weight women. In this group of women, the prevalence of blood loss >1,000 ml was 34.9% versus 9.3% in nonobese women [138].

Thromboembolic disease is more frequent in obese women [46, 72]. However, pulmonary embolism could not be shown to be increased in obese women [37]. The low incidence of this serious complication probably makes it difficult to find statistical evidence. No study has had large enough samples, so there is inadequate statistical power for reliably detecting differences in the rate of this complication. If given, prophylactic anticoagulation should probably be tailored to the patient and related to total body weight. Evidence for a weight-based administration of this prophylactic medication is still lacking, but in obese patients it is recommended. The fashionable low-molecular-weight heparins can be administered once a day, which makes their use easier and increases compliance. A small study examined, after a single prophylactic dose of enoxaparin, the plasma levels of antifactor Xa—which is thought to correlate with the antithrombotic effect—in relation to body weight and found a strong negative correlation between body weight and antifactor Xa [142]. The initial administration is most effective if given between <2 h before and 6–8 h after the operation [143]. The duration of prophylactic anticoagulant therapy after surgery is still under debate [144]. In acutely ill patients, the venous thromboembolism risk is similar to that in surgical patients. In these patients, at least 2 weeks of prophylactic anticoagulation therapy is generally recommended [145].

Postpartum urinary complaints such as stress incontinence are more frequent among obese women, but they are also related to parity and the mode of delivery [146]. Postoperative urinary tract infections are also more frequent in obese women [37].

Consequently, hospital stays of obese women are longer than those of normal-weight women after both vaginal delivery and caesarean section [5, 134, 138].

Weight retention postpartum

With an average amount of weight gain during pregnancy, weight retention will be 1 kg. This amount is above the normal weight gain of 0.45 kg/year with age. Excessive weight gain during pregnancy is assumed to be associated with the development of obesity postpartum [147]. Other possible contributing factors are maternal age, parity, lifestyle factors, and pregravid maternal weight [148]. The influence of pregravid BMI is questionable. A longitudinal study in already obese women showed only a tendency to develop central obesity [149]. In the large Swedish SPAWN (Stockholm Pregnancy and Women's Nutrition) study, postpartum weight retention was influenced not by pregravid overweight but by the amount of weight gain [150]. Postpartum weight loss is therefore essential for preventing permanently increased weight. Lactation is considered to promote weight loss, but weight loss is highly variable among lactating women. The observation that breastfeeding fails more often in obese women can be substantiated by the decreased prolactin response to suckling in the first week postpartum [151]. Losing weight during breastfeeding is safe and does not interfere with neonatal weight gain [152].

Special considerations

The increasing height and weight of women who become pregnant demand adaptations of the hospital furniture. In the last decades, not only weight but also a small increase in height took place; over the last 40 years, women in their fertile period became 1–1.5 cm taller [153]. Standard hospital beds, wheelchairs, operating tables, imaging equipment, and even scales are not designed to accommodate the growing number of extra-large patients. For extremely obese patients, two standard 50-cm width operating tables may be necessary. Scales suited for obese patients are necessary not only to measure weight and evaluate weight gain during pregnancy but also for calculating medication dosages.

An anecdotal case report described a serious time loss after one of the wheels of the delivery bed broke on its way to the operating theatre [125]. It is advisable to use a delivery bed that may be used in all stages of delivery without the need to move the patient onto another bed. The delivery bed should be easy to move around and even be suited for caesarean sections for morbidly obese patients.

So-called hanging toilets that are present in many modern hospitals have to be shored up or replaced by floor-mounted toilets.

Many computed tomography and magnetic resonance imaging scanners have weight restrictions.

Nursing care of obese patient asks for ergonomic adaptations and knowledge about the special risks involved in caring for these patients. More nurses are necessary to care for morbidly obese patients.

In morbidly obese women, home delivery should be avoided. In countries such as the Netherlands, where home deliveries are still routine, transferring a morbidly obese patient to the hospital in the event of delivery complications may be quite a problem. More personnel are needed to lift and transport the patient. Firefighters have occasionally been used to transfer patients to the waiting ambulance, and special stretchers have been developed for morbidly obese patients. If necessary, the patient can be transported on the floor of the ambulance.

Prevention

The ultimate goal of preventive measures is for individuals not to become obese at all. Once obesity is present, reducing the overweight is difficult and disappointing. Preferably, obese women should reduce weight before conceiving. In women who lost more than 4.5 kg between two pregnancies, the risk of developing gestational diabetes decreased by nearly 40%. Women who gained this amount of weight between their pregnancies likewise showed a similar increase in the incidence of gestational diabetes [49]. The ideal amount of weight loss in 6 months is 10% of the total body weight. This not only keeps weight loss within safe limits but also guarantees a longer-lasting effect [154]. Weight reduction can be achieved by dietary measures, physical activity, and medication. For long-term obesity management, two specific drugs are available, sibutramine and orlistat. Neither of these drugs is advised for use during pregnancy or breastfeeding, but so far, no adverse events have been seen when used during human and animal pregnancy. Two case series report the accidental use of sibutramine during the first trimester. After this exposure, nine normal healthy babies were born [155, 156].

Bariatric surgery is a method of weight reduction that may have consequences for a consecutive pregnancy. According to the 1991 National Institute of Health Consensus Developmental Conference, bariatric surgery is the only effective treatment for morbidly obese patients [157]. The following conclusions were drawn at this conference: (1) patients seeking therapy for severe obesity for the first time should be considered for treatment in a nonsurgical programme with integrated components of a dietary regimen, appropriate exercise, and behavioural modification and support, (2) gastric restrictive or bypass procedures could be considered for well-informed and motivated patients with acceptable operative risks, (3) patients who are candidates for surgical procedures should be selected carefully after evaluation by a multidisciplinary team with medical, surgical, psychiatric, and nutritional expertise, (4) the operation should be performed by a surgeon substantially experienced in the appropriate procedures and who works in a clinical setting with adequate support for all aspects of management and assessment, and (5) lifelong medical surveillance after surgical therapy is a necessity. This view was confirmed by a recent Cochrane review [158].

Most patients who undergo bariatric surgery are women. Surgical procedures for morbid obesity may be classified according to the digestive after-effects brought about by the particular procedure. The first category is restrictive operations that limit caloric intake. The second category is bypass procedures that produce malabsorption of nutrients and vitamins. In both categories, patients often need food supplements after bariatric operations. Otherwise, anaemia because of iron, folate, and vitamin B12 deficiencies may develop. During pregnancy, a patient's nutritional status needs to be followed closely.

Vertical banded gastroplasty is nowadays the most frequently performed operation; it can be carried out either laparoscopically or by laparotomy. An adjustable gastric band beneath the oesophageal/gastric junction is applied, and a small gastric pouch with a capacity of < 30 ml is created. The width of this gastric band can be varied by injecting fluid into a reservoir port. This allows adaptation during pregnancy in case of complaints of nausea and vomiting or excessive weight gain [159].

Some case reports describe maternal and foetal complications during pregnancies after bariatric surgery [45, 160]. Maternal and foetal death after Roux-en-Y gastric bypass surgery caused by small bowel herniation was recently reported; this patient was still morbidly obese and developed complications when she was 31 weeks pregnant [161]. So far, this is the only report of fatal maternal complications during pregnancy after bariatric surgery. Several larger studies describe no adverse perinatal or maternal outcomes [159, 162–165]. The largest study so far comprised 298 deliveries after open or laparoscopic bariatric procedures [166].

In the rapid phase of weight reduction after surgery, it seems preferable for women not to conceive. After body weight stabilises, maternal malnutrition is supposed to have ceased. It is wise for women to use contraception during this period, which generally lasts 1 year, because ovulation may resume during weight reduction. Oral contraceptives are probably less reliable in these patients [167, 168].

In three series of women who underwent bariatric surgery for morbid obesity, fertility and obstetric performance improved substantially after the operation [169, 170, 171]. Spontaneous abortions and foetal macrosomia were reduced after these procedures.

Contrary to all expectations, the caesarean section rate in women after bariatric surgery was still twice as high as in the general population. Bariatric surgery remains, even after controlling for confounders, an independent risk factor for caesarean section. The authors explain this phenomenon as caregiver bias [166].

It can be concluded that pregnancy after bariatric surgery is safer than being pregnant while still being obese.

Conclusions

Ideally, maternal obesity should be treated before conceiving. Treatment of ovulatory disorders is preferably preceded by weight reduction. Once pregnant, obese women should be offered dietary support. The aim of this support is to establish proper dietary measures during pregnancy and to prevent excessive weight gain. However, weight loss must be avoided.

During pregnancy, obese women should be followed closely with respect to the development of preeclampsia and GDM (Table 3). Screening for GDM should commence at 20 weeks of gestation and be repeated at regular intervals. The 1-h postprandial plasma glucose test is useful as a screening tool.

Around 20 weeks of gestation, a foetal anomaly scan should be scheduled. In morbidly obese women, alternative ways of performing an ultrasound can be employed. Foetal growth must be followed closely, and if macrosomia is present, the safest mode of delivery must be decided upon.

Table 3 Clinical recommendations

Pregnancy:
For calculating BMI, the prepregnant or early pregnancy body weight must be used. The BMI later in pregnancy is not useful as a parameter for obstetric risk assessment.
Subclinical hyperglycaemia has to be screened at the first visit and preferably before pregnancy. Screening for gestational diabetes mellitus should be started at 20 weeks of gestation and repeated every four weeks. The 1-h postprandial plasma glucose test is a useful screening tool. The 2-h 75-g oral glucose tolerance test is the optimal diagnostic test.
Blood pressure measurements must be done with a sphygmomanometer with an appropriate cuff size. In morbidly obese patients, the forearm or ankle can be used.
To prevent neonatal complications, weight gain should not be excessive. Suboptimal or negative weight gain should be avoided.
Foetal weight estimation is not greatly influenced by obesity.
The rising incidence of congenital anomalies with increasing maternal weight is an indication for structural ultrasound.
Structural ultrasound should be performed vaginally during the first weeks and abdominally after 18 weeks of pregnancy to improve visualisation.
Delivery:
Await spontaneous labour, if possible. Employ active management of labour.
Institute routine antepartum screening by the anaesthesiologist.
Consider early administration of regional anaesthesia.
In caesarean section, a transverse incision is advised. The subcutaneous layer must be closed separately and drained.
Puerperium:
Be aware of the increased chance of postpartum infections and blood loss.
Adapt dosage and length of prophylactic anticoagulation to the maternal weight and clinical situation.
Promote breastfeeding.
Special considerations:
Evaluate the local logistic situation.
Avoid home deliveries.
Prevention:
Stimulate weight loss as much as possible before pregnancy.
Consider bariatric surgery, especially in morbid obesity.

In an uneventful pregnancy, spontaneous delivery can be awaited. The progression of labour should be followed closely. The higher prevalence of anaesthetic problems may play a role in deciding when to perform a caesarean section. If a caesarean section is needed, a transverse incision is preferable. The subcutaneous layer should be closed with interrupted sutures, and subcutaneous drainage must be considered.

Postpartum infections are more frequent in obese women. Thromboprophylaxis may be indicated, in which case the anticoagulant dosage must be adjusted to the patient's weight.

In the immediate postpartum period, it is important for the woman to lose weight to reduce permanent weight gain. Breastfeeding may promote further weight reduction.

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